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# In Memoriam Professor Shuichi TASAKI (1958-2010)(Perspectives of Nonequilibrium Statistical Physics- The Memory of Professor Shuichi Tasaki-)

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## *In Memoriam* Professor Shuichi TASAKI (1958-2010)

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Professor Shuichi Tasaki passed away unexpectedly on 6 June 2010 in Tokyo. He will be remembered for his theoretical achievements in condensed matter physics, in nonequilibrium statistical mechanics, and especially, in the mathematical theory of irreversibility.

Shuichi Tasaki was born on 26 April 1958 in Oita City, Japan. He obtained a BSc degree in physics from the Faculty of Science and Engineering of Waseda University in 1981 and a MSc degree in condensed matter physics from Kyoto University in 1983. He received his PhD thesis also from Kyoto University in 1989. The same year, Shuichi Tasaki arrived in Brussels to work with Professor Ilya Prigogine as postdoctoral research associate at the International Solvay Institutes for Physics and Chemistry. During his stay of four years at the Université Libre de Bruxelles, he opened up the way to new progress in nonequilibrium classical and quantum statistical mechanics. In 1993, Shuichi Tasaki returned to Japan as researcher at the Institute for Fundamental Chemistry founded in Kyoto by Professor Kenichi Fukui and, in 1997, he became associate Professor at Nara Women's University. In 2000, he took a position of associated Professor in the Department of Applied Physics at the Faculty of Science and Engineering of Waseda University, where he was promoted Professor in 2002.

Shuichi Tasaki was an outstanding theoretical and mathematical physicist. His research history is the following.

### **Early research**

During his master thesis in 1982-83, Shuichi Tasaki worked on the electric conductivity in the charge-density-wave phase of NbSe<sub>3</sub>, which is a quasi one-dimensional material. In this low-temperature phase, which was first predicted by Fröhlich, the electric conductivity shows several unexpected behaviors such as a nonlinear dependence on the applied field and the generation of periodic 'noise' under the application of a *dc*-field. Shuichi Tasaki gave a qualitative explanation of these phenomena based on a classical dynamical model by using the multiple scale method

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of nonlinear oscillator theory. The results were published in *Progress of Theoretical Physics* **70** (1983) 920.

Thereafter, Shuichi Tasaki published a study in *Progress of Theoretical Physics* **75** (1986) 445 on the properties of the periodic  $s$ - $d$  model. In some materials such as  $\text{UPt}_3$ , quasiparticles with very heavy effective mass appear as the result of the so-called  $s$ - $d$  interaction between conduction and localized electrons and they are considered to be responsible for new-type superconductivity. In this context, Tasaki gave a mathematical justification to the theory by Tsuneto and Kato, in which the singlet state between a conduction and a localized electron is treated as a vacuum and their excitations as quasiparticles.

His Ph.D. thesis was devoted to the theory of the magnetic properties of adsorbed  $^3\text{He}$ , which manifests a ferromagnetic behavior, although bulk  $^3\text{He}$  does not. Shuichi Tasaki investigated this phenomenon based on a model where the indirect exchange mechanism by Ruderman, Kittel, Kasuya and Yoshida is responsible for the origin of ferromagnetism. The most important aspect of this model is that liquid layers are described as almost localized fermionic systems. Accordingly, the model predicts that the layer width strongly influences the Curie temperature, albeit the Curie constant and the susceptibility are weakly influenced. Both predictions are in very good agreement with experiments. Moreover, the same model predicts a new ordered state at very low magnetic field, which can explain observed NMR frequency shifts. The results were published in a series of papers: *Progress of Theoretical Physics* **79** (1988) 1311; *ibid.* **80** (1988) 922 E; *ibid.* **81** (1989) 946; *ibid.* **82** (1989) 1032; *Physica B* **165-166** (1990) 703.

### Postdoctoral research with Professor Ilya Prigogine

During his stay of four years at the Université Libre de Bruxelles from 1989 until 1993, Shuichi Tasaki was postdoctoral research associate by Professor Ilya Prigogine at the International Solvay Institutes for Physics and Chemistry and he contributed to the theory of irreversibility thanks to his exceptional mastery of mathematical analysis and, especially, of functional analysis and the theory of  $C^*$ -algebras.

In collaboration with Prof. I. Prigogine and T. Petrosky, Shuichi Tasaki published in *Physics Letters A* **151** (1990) 109 and *Physica A* **170** (1991) 306, a study of the quantum Zeno effect motivated by the observation of this effect in a trapped ion system.

With furthermore Dr. H. Hasegawa, the collaboration found that, in the solvable Friedrichs model of decaying systems, the previously formulated subdynamics approach is equivalent to the complex eigenvalue problem for the Hamiltonian. The time ordering rule was incorporated with the usual perturbation scheme to obtain a complete set of eigenfunctions and corresponding complex eigenvalues, splitting the unitary time evolution of the system into two semigroups with broken time symmetry. The work was published in *Foundations of Physics* **21** (1991) 263;

*Physica A* **173** (1991) 175; and *Chaos, Solitons and Fractals* **1** (1991) 3.

In a paper by Lee and Tasaki published in *Physica A* **182** (1992) 59, the subdynamics formalism was generalized to driven systems with an explicit time dependence. A recursion formula was used to construct a complete set of projection operators, which significantly simplifies the calculation compared to previous formulations.

In this direction, Shuichi Tasaki obtained fundamental results in the complex spectral theory of time-evolution operators for quantum and classical systems. At the XXth Solvay Conference on Physics held 6-9 November 1991 in Brussels, he presented a second-quantization formalism based on complex instead of real frequencies with the aim to represent the time asymmetric evolution of systems.

Thereafter, Tasaki applied the complex spectral theory to two typical maps, i.e., the noninvertible  $\beta$ -adic Renyi map and the invertible  $\beta$ -adic baker transformation in order to obtain the complex set of eigenfunctions corresponding to the Pollicott-Ruelle resonances and describing the decay of time correlation functions. For these maps, a rigorous mathematical meaning was given to the formally obtained spectral decompositions with decaying eigenfunctions in terms of rigged Hilbert spaces. Moreover, in the case of the Renyi map, the conversion of the spectrum of the Frobenius-Perron operator from the unit disk to isolated eigenvalues was explained by changing the domain of definition of this operator. In the case of the baker map, the splitting of the unitary evolution into two semigroups was explicitly shown. This construction was later extended to other piecewise-linear maps.

Moreover, Shuichi Tasaki applied the second quantized version of the complex spectral theory to study the stability of flat space-time solutions in a cosmological model by Gunzig and Nardone.

## Research at Kyoto's Institute for Fundamental Chemistry and Nara Women's University

In September 1993, Shuichi Tasaki took a position of researcher at the Institute for Fundamental Chemistry founded in Kyoto by Professor Kenichi Fukui, while continuing his collaboration with Brussels' group on nonequilibrium statistical mechanics.

At the end of his stay in Brussels, Shuichi Tasaki and myself had started a long lasting collaboration on spatially-extended models of diffusion called multibaker maps, justifying Fick's law on a fundamental ground by the explicit construction of the nonequilibrium steady states and the diffusive modes of relaxation towards the thermodynamic equilibrium state in consistency with microreversibility. In this collaboration, the nonequilibrium steady states of the multibaker map was shown to be given in terms of Takagi nondifferentiable functions while the spectral decomposition of the corresponding Frobenius-Perron operator could be expressed in terms of fractal de Rham functions. This study was later extended to a further multibaker

model including an energy variable, in which the thermodynamic entropy production could be calculated. Moreover, the spectral decompositions of the Liouvillian time evolution of dissipative dynamical systems undergoing pitchfork or Hopf bifurcations were also constructed.

On the new advances – he contributed to so much – in our understanding of the arrow of time, Shuichi Tasaki wrote a Blue Backs book in Japanese entitled “Time’s arrow from the viewpoint of chaos theory” which was published in 2000.

In parallel, Shuichi Tasaki worked on several aspects of the quantum dynamics of decaying systems. In collaboration with T. Harayama and A. Shudo, he published several papers on eigenvalue problems in classically chaotic quantum billiards. He also worked in collaboration with K. Maekawa and T. Yamabe on the effect of chirality on the optical properties of carbon nanotubes.

## Research at Waseda University

In April 2000, Shuichi Tasaki got his position at Waseda University in the Department of Applied Physics, Faculty of Science and Engineering.

He then undertook research on nonequilibrium steady states in open quantum lattice systems using the mathematical formalism of  $C^*$ -algebras. In collaboration with T. Matsui, he constructed the MacLennan-Zubarev nonequilibrium ensembles for a class of open large quantum systems and proved a version of the fluctuation theorem in this framework. More recently, Tasaki also worked with D. Andrieux, T. Monnai, and myself on the fluctuation theorem for currents in open quantum systems, publishing together in 2009 a proof of the steady-state version of this theorem by considering transient time-reversal symmetry relations in some appropriate long-time limit.

At Waseda University, Tasaki’s research activities with his collaborators and his students became diversified on various topics of condensed matter theory and quantum physics. In particular, he contributed to the level-spacing statistics of classically integrable systems along the lines of the Berry-Robnik approach, to the control of coherence, to current fluctuations in an AB ring with a quantum dot, to the assumption of initial factorization in weakly coupled systems, as well as to equilibrium and nonequilibrium phase transitions. One of his last contributions is a theory of the nonequilibrium Peierls transition to interpret experimental observations of giant nonlinear conduction in charge-ordered organic materials. This theory was developed by combining condensed matter physics with nonequilibrium statistical mechanics and appears as a synthesis of Tasaki’s deep insights into two of his favorite fields.

Shuichi Tasaki has also publications in dynamical systems theory on the spectral characterization of anomalous diffusion in periodic piecewise-linear intermittent maps and on the asymptotics beyond-all-orders approach for maps with reconnection of stable/unstable manifolds.

The sudden death of Professor Shuichi Tasaki came as a shock the 6th of June 2010. The communities working in nonequilibrium statistical physics and the theory of irreversible processes have lost a leading figure who has greatly influenced the development of these fields by his seminal contributions during the last two decades. We owe him profound and inspiring theoretical results he achieved with his extraordinary and unique mathematical virtuosity. He will be fondly remembered as an exceptionally brilliant scientist and also as a deeply humane gentle person.

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